Short Communication

In Situ Device for Detection of Oil Spill in Seawater

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Abstract
The purpose of this study was to design an innovative, real time, cost effective, and environment friendly in situ technique for the surface measurement of oil spill thickness. The technique was based on the concept of the electrical conductivity to characterize and to measure the thickness of an oil layer in seawater. The system was designed to monitor the seawater pollution continuously and to send an alarm if the oil level exceeds a certain limit. The results of this study are very important as they may contribute to the development of advanced practices in oil spill detection.

Keywords: Oil spill detection in seawater, In situ technique, Electrical conductivity, Real time system, Electrochemical detector

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Huge amounts of oil are produced every year to fulfill human and industrial requirements. However, significant amounts spill during transportation or production. Therefore, oil spills are a major problem in most countries because of their detrimental impacts on the environment and economy. Oil with its aromatic compounds is categorized as a toxic material that can destroy marine life as well as damage habitat for terrestrial animals and humans.

Oil spills enter seawater from a wide range of sources including: accidents or grounding of tankers; oil exploration and production; cargo tank washings at sea; and discharge of ballast water by ships into the sea. Generally, a significant amount of oil pollution of the world's oceans is caused by shipping accidents. The world has seen many oil spill accidents in different countries and for different reasons [1].

An oil spill which occurs near a coastline will always impact on more living organisms than one which occurs in the open ocean. This is simply because coastal areas are home to a much more concentrated and diversified population of marine life than the open ocean [2]. Nevertheless, all oil spills have an impact on marine organisms, and oil from open ocean spills can end up contaminating beaches hundreds of miles away. This has highlighted the need for authorities to work together, especially in the coastal areas that suffer from oil spills. During the last thirty years, therefore, pollution of the oceans of the world has become a matter of increasing international concern.

Earlier and more reliable detection of oil spills means faster containment and reduced clean-up costs. Hence, the rapid detection of oil pollution in seawater is an essential part of oil pollution prevention. It is important for minimization of environmental and financial impacts.

Several general reviews of oil spill remote sensing have been reported [3, 4]. These reviews showed that there was progress in oil spill remote sensing, although this progress has been slow. In general terms, remote sensing is the detection of phenomena at a distance from the object of interest using human capabilities or special sensors. Modern remote sensing instruments are normally based on optical, electronic or chemical techniques. Laser fluorosensors are well known for their ability to positively detect and classify petroleum oils. Brown and Fingas [4] developed a laboratory sensor to measure the absolute thickness of oil on water slicks. The sensor employed three lasers to produce and measure the time of flight of ultrasonic waves in oil and hence provided a direct measurement of oil slick thickness.

The use of human vision alone is not considered remote sensing. However, it still forms the most common technique for oil spill surveillance. In the past, major projects using only human vision were mounted with varying degrees of success [5].

Optical techniques are the most common means of remote sensing. Cameras, both still and video are common because of their low price. In recent years, visual or camera observation has been enhanced by the use of GPS (Global Positioning Systems). Direct annotation of video images with GPS information is possible and provides useful documentation [6, 7].

Video cameras are often used in conjunction with filters to improve the contrast, in a manner similar to that noted for still cameras. This technique has limited success for oil spill remote sensing because of poor contrast and lack of positive discrimination. Despite this, video systems have been proposed as remote sensing systems [8]. With new light-enhancement technology (low lux), video cameras can be operated even in darkness [7].

The use of visible techniques in oil spill remote sensing is largely restricted to documentation of the spill because there is no mechanism for positive oil detection. Furthermore, there are many interferences or false alarms. Sun glint and wind sheens can be mistaken for oil sheens. Biogenic material such as surface weeds or sunken kelp beds can be mistaken for oil. Oil on shorelines is difficult to identify positively because weeds look similar to oil and oil cannot be detected on darker shorelines. In summary, the usefulness of the visible spectrum for oil detection is limited. It is, however, an economical way to document spills and provide baseline data on shorelines or relative positions [7].

In spite of rigorous controls, oil spills do still occur and so deterioration of water quality continues at a high rate. An alternative for detecting oil spills in seawater is by designing an innovative in situ technique that can be used for earlier oil spill detection. It must ensure that oil spills are reliably detected. This earlier spill detection will prompt slick containment which accordingly results in a significant reduction in clean-up costs. For successful operation of this technique, it must be easy to carry and install at different locations as well as depths of marine water. In addition, it must be safe and its use should not create any additional environmental hazards.

Oil possesses a number of thermal properties that make it distinguishable from seawater (e.g., heat capacity and thermal conductivity). Electrical conductivity is the ability of an aqueous solution to conduct an electric current and it is a measure of how well a material accommodates the transport of electric charge. The electrical conductivity of oil is much lower than that of seawater. Hence, the oil layer acts as a layer of resistance to the flow of the current.

Thus, this study attempts to reach the goal of earlier detection of oil pollution in seawater through development of an innovative in situ technique. The technique was based on the concept of an electrical conductivity measurement to characterize the oil in seawater. Electrical conductivity measurements were used in characterizing the oil-in-water system by applying voltage between two electrodes. First, the conductivity of the seawater was examined and it was recorded. Second, the conductivity of seawater that included oil layer was checked. It was found that the conductivity of the polluted seawater reduced upon addition of oil into the seawater. Therefore, the conductivity of the polluted seawater was small compared to that of the seawater.

A preliminary bench scale design was first constructed to measure the conductivity of seawater and compare it to that of the oil polluted seawater. Figure 1 depicts in detail the whole system of this preliminary design. The design consists of five main components: glass container (1 litre) which holds the seawater; DC power supply (0 – 15 V) to provide electrical current or voltage difference; two electrodes (conductors); wires; and digital multimeter to measure current that was given by the DC power supply.

The oil layer detection in seawater was examined by slowly adding a small amount of crude oil to the glass container that contained the seawater so as to form an oil layer. The reading of the multimeter (i.e., electrical conductivity) was compared with that of the seawater. The results indicated an abrupt decrease in the multimeter readings when the seawater was covered by an oil layer. This decrease in conductivity between the two electrodes was due to the high resistance of the oil layer which acted as an insulator.

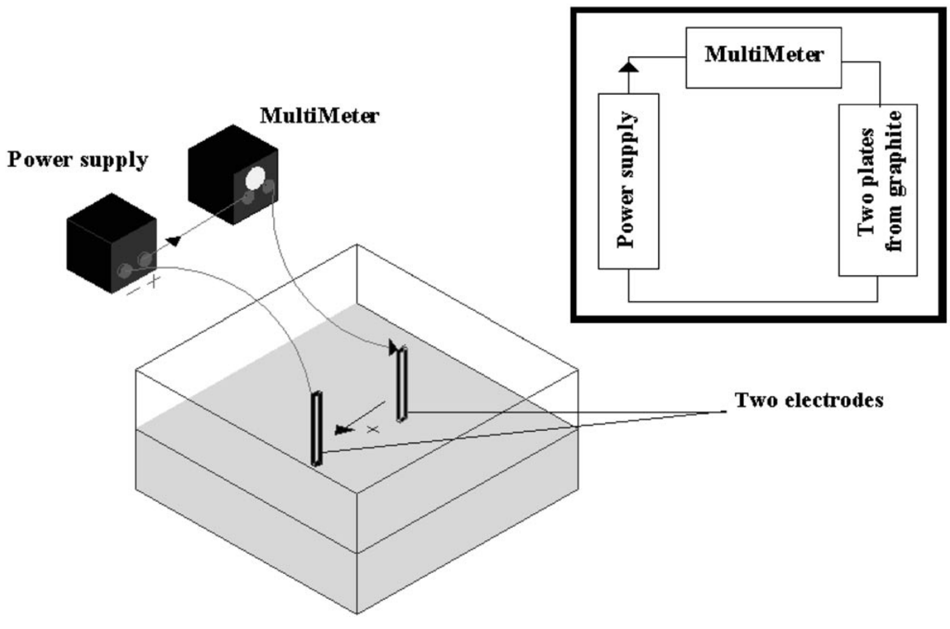


Fig. 1. The electrical conductivity measuring device.

An innovative technique was then designed to develop an operative real time system for oil spill detection. The system provides an in situ technique for detection of oil pollution in seawater. It can work in such a way that monitoring of seawater pollution can simultaneously detect the oil layer and send an alarm if the oil level exceeds a certain limit. Figure 2 shows the design and its main components. The design consists of seven main components: glass container (1 liter) which holds the seawater; two electrodes (conductors); potentiometer; computer program; wires; motor (i.e., moving the plates up and down); and DC power supply (0–15 V).

The system was designed to send an alarm if the level of the oil increased to a certain threshold. Also, the system was designed to data log the status information about seawater conditions every 15 minutes or at any time interval selected on the computer. This helps not only in finding the thickness of the oil layer but also for determining the speed of the oil layer (since the downward distance and the time between the two steps are known). Finally, the data was displayed in the program screen with the thickness and the speed of the oil layer.

The designed system is easy to use. It may be installed at different locations in the marine water and at different depths as well. In addition, it has the ability to be connected locally with a data logger. The system in reality will be constructed in a small box that will float in seawater (Figure 3). It will consume only a small amount of electricity. Hence, the total cost will be very low compared with other techniques that have been used to detect oil pollution. Moreover, safety concerns have been taken into account since the voltage supply is very low.

Figure 4a shows the current flow when there is no crude oil in the seawater whereas Figure 4b depicts the current flow when there is oil pollution in the seawater. It can be seen that the electrical circuit in both Figures consisted of two paths. The first path was the combination of the power supply, DC-motor and a variable resistance (R), whereas the second path consisted of the power supply, seawater, and a variable resistance (R). It should be noted that the first and the second variable resistances (R) were used for the purpose of controlling the current flow through the motor and the relay, respectively.

If there is no oil in the seawater (Figure 4a), then the electrical current would flow in the seawater side. No flow would pass through the motor side because of the higher resistance on this side (i.e., motor and variable resistance) as compared with that of the seawater side. When the relay is opened, then no current would flow through the motor side. When oil is present in the seawater (Figure 4b), the direction of the electrical current in the circuit changes. Since the relay circuit is closed, the current would flow in the motor. Therefore, the motor rotates and as a result the two electrodes move downward into the polluted seawater.

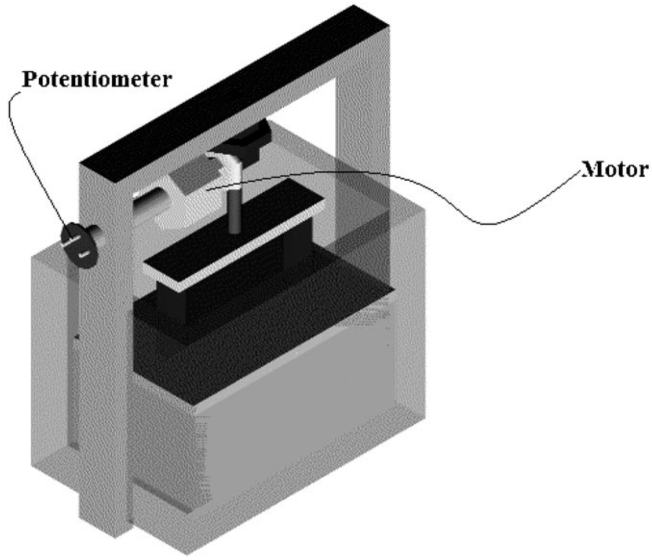


Fig. 3. Construction of real time system for oil spill detection in seawater.

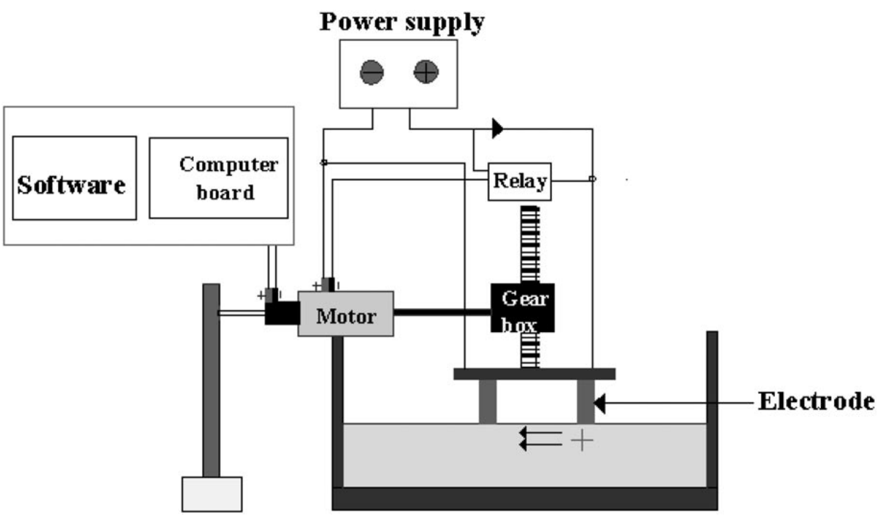
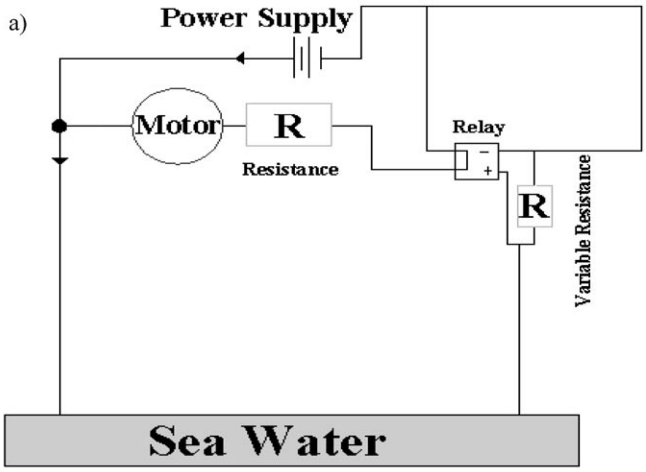


Fig. 2. The electrical circuit of the real time system for oil spill detection in seawater.



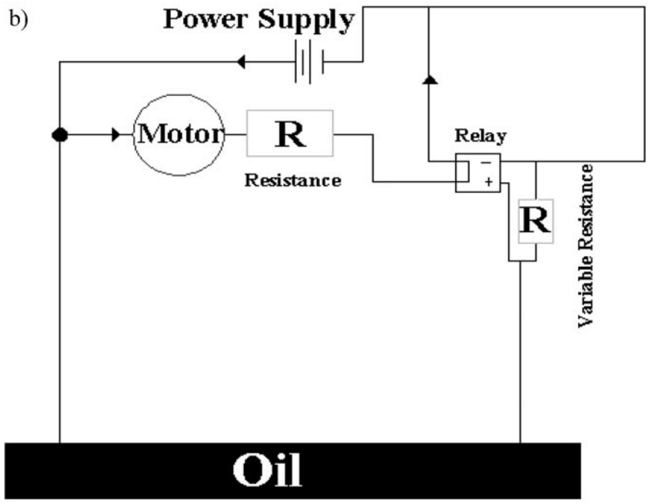


Fig. 4. The current flow a) when there is no crude oil in the seawater and b) when there is oil pollution in the seawater.

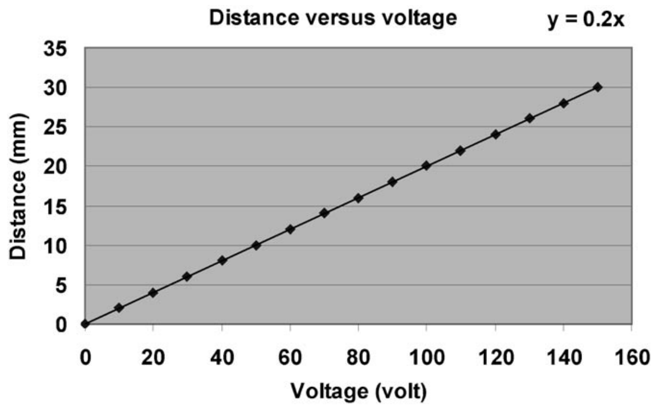


Fig. 5. Calibration curve between the downward distance and the measured voltage.

This downward movement of the two electrodes continues as long as the water is polluted with oil. This downward movement continues until the electrodes meet a non-polluted seawater layer (beneath the oil layer). The direction of the flow of the current would change again so it passes through the seawater. The motor then stops its rotational movement. As a result, the electrodes stop their downward movement. The distance that the motor moved could be calculated.

Calibration of the designed system was carried out in order to find out the relationship between the downward distance (thickness of the oil layer) and the voltage coming from the potentiometer (i.e., volt signal received by the computer through the data logger). Each full revolution of the potentiometer corresponds to a downward distance of 2 mm which is equivalent to 10 V. The results of the calibration are described in Figure 5.

With respect to social impacts, the design is helpful and efficient because it can control and detect oil pollution problems in the seawater. Early warning capabilities and rapid response of the designed system will address potential human health and marine life hazards from unintentional exposure associated with the oil spill pollution. Furthermore, the designed system is clean, has no risk and is environmentally friendly as well. The construction materials will not generate any air, water or land pollutants.

The system is the most suitable choice when considering human and environmental demands for the following:

- To develop a compact and cost-effective automated oil spill sensing technology for early detection and alarm of petroleum hydrocarbon leaks and spills.
- To recognize the positive potential of detecting oil pollution in seawater by means of reducing the cost of pollution removal.
- To avoid and abate any adverse environmental or health impact from defense utilization of oil detection process.
- To develop novel instrumentation to deal with the challenges of monitoring and assessing the quality and status of hostile marine environments.
- To develop a measurement method for oil detection that can save a significant amount of money.

This study conducted preliminary research into an in situ technique for early detection of oil pollution in seawater. The designed system made it possible to not only detect oil in seawater, but also to determine the thickness of the oil layer. The design was experimentally tested by using different types of oil and was used to determine the average speed of the oil spill. The design was simple, cost-effective, automated, compact, with low energy consumption, and could be constructed at any time and at any location. The result of the present work is very important since it can be used to tackle the oil spill problem and hence minimize damage caused.

Further studies need to be undertaken to better understand the effects of other variables on the technique. Future work to validate the method is also recommended by taking into account examples of measurement of real samples.

Experimental

Preliminary Experimental Design

In carrying out the experiment, an amount of seawater (300 mL) was placed in a glass container. The electrical circuit was prepared in such a way that it consisted of two electrodes that were connected by wires with the power supply and the multimeter (Figure 1). All the components were connected in series. The electrical circuit consisted of two electrodes that protruded into the seawater. A constant voltage (V) was applied across the electrodes by using the DC power supply. An electrical current (I) flowed through the seawater due to this voltage and was proportional to the concentration of dissolved ions in the seawater (i.e., the more ions, the more conductive the seawater) resulting in a higher electrical current that was measured electronically by the multimeter. The oil layer detection in seawater was then examined by slowly adding a small amount of crude oil in the glass container so as to form an oil layer. The new reading of the electrical current of the multimeter was recorded. This reading was compared with that of the seawater.

Final Experimental Design (Real Time System)

In carrying out the experiment, an amount of seawater (300 mL) was placed in a glass container. The electrical circuit was prepared in such a way that it consisted of two electrodes that were connected by wires with the power supply and the motor. The power supply was connected in parallel with the electrodes as well as with the DC motor. The whole system is depicted in detail on Figures 2 and 3. The electrical circuit consisted of two electrodes that protruded into the seawater (i.e., the two electrodes were adjusted to touch the surface of the seawater in the container), power supply, and the motor. A constant voltage (V) was applied across the electrodes by using the DC power supply. Due to this voltage in the electrical circuit, an electrical current (I) flowed through the electrical circuit. All the generated electrical current (I) in the circuit was expected to flow through the seawater side (less resistance) and therefore there no electrical current would flow through the motor side. This is because of the existence of the dissolved ions in the seawater that makes the seawater more conductive in comparison to the motor side. Hence, the electrical resistance was much higher in the motor side than that in the seawater side. This caused all the electrical current (I) to flow through the seawater side across the two electrodes. As a result, the motor does not rotate and so the two electrodes do not move downward in the seawater. The two electrodes stayed in their position at the surface of the seawater. The readings of the electrical current that passed through the seawater side across the two electrodes were taken and saved by the computer.

The oil layer detection in the seawater was then investigated by slowly pouring an amount of oil (150 mL) into the glass container so as to form an oil layer. A constant voltage (V) was again applied across the electrical circuit by using the DC power supply. Due to this voltage in the electrical circuit, an electrical current (I) flowed through the electrical circuit. In this case, all the generated electrical current (I) in the circuit was expected to flow through the motor side (less resistance) and therefore there was no electrical current flowing through the seawater side (high resistance due to the presence of the oil layer). Hence, there was no electrical current passing across the two electrodes. This was due to the high resistance of the oil layer which worked as insulator. The current flowing through the motor was used to rotate the motor (rotational movement) and the gear box was used to convert the rotational movement of the motor into downward movement. This resulted in the movement of the two electrodes downward into the polluted seawater. Hence the two electrodes continued to move downward within the oil layer as long as the water was polluted. This downward movement of the two electrodes continued until the electrodes met a clean layer of seawater beneath the oil layer. The signal then was given to the computer to stop rotation of the motor and so the downward movement of the two electrodes. The computer program measured this downward movement of the two electrodes and considered it as a measure of the thickness of the oil layer. It should be noted that a potentiometer was connected with the motor. The function of this potentiometer was to convert the rotational movement of the motor into a volt signal that the computer could understand.

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